CHAPTER VII

ENVIRONMENT AND OTHER EXTERNALITIES

VII.1. ENVIRONMENTAL CHALLENGE

During the life cycle of a road or a network the responsibilities and life styles of people, their travel demands, and communities as a whole will change. The road network has to be adapted to these new circumstances. Unfortunately, such changes are highly case specific. The elaboration of a checklist of the major prevailing environmental issues, or the enumeration of pro-active options, is therefore an immensely tedious undertaking. That different interest groups perceive the issues and options in different ways, only makes such an undertaking more complex. However, although no generally applicable agreement can be reached on goals and objectives, even problem definition, nor the monetary values of intangible benefits, an agreement is possible on the course of action needed. This provides a window for contributing to the mitigation of complex environmental problems.

In the last decade awareness of the value of the environment has increased in the industrialized world. Environmental considerations in planning, design and construction of new roads have expanded. The costs of new roads to fulfill expectations of the public are today remarkably higher than just a decade ago. Equally remarkably, there exists widespread willingness by the politicians, officials and the general public to pay for these costs. The higher costs for the construction of tunnels or aesthetically pleasing viaducts, for park renovation, for sophisticated control systems and other environmental mitigation measures also increase the costs of rehabilitation and maintenance of these structures.

Environmentally sensitive construction and maintenance of roads are desirable because they provide tangible benefits: cleaner air and more pleasing appearance of the environment; protection of neighbourhoods; increased quality of life; and higher value of land and homes. Access without visible nuisance of the roads is a highly valued commodity. Another instance of this value capture is in urban centres where aesthetically pleasing environmental spaces have created thriving business conditions.

Environmental assessment (EA) is already required, starting in advance planning phases for new road constructions in all OECD countries. But no impact assessment is mandatory for rehabilitation and maintenance. Apparently the thinking is that the road is there, it carries traffic; these are facts. Often, however, rehabilitation or maintenance of a road takes place in new circumstances and it is adapted to take on "new obligations".

Investment in the environment in the context of road works is already substantial; presently 5-15 per cent of the road costs are environment related expenditures. This figure attests in a concrete way to the importance and necessity of caring for the road and traffic environment. Road rehabilitation presents an opportunity to enhance the value of the environment. Rehabilitation and maintenance are now experiencing a change in concept and content: their purpose is to preserve the value of the investment **and** to improve the environment[1]. It is therefore vitally important to promote training of personnel in environmental assessment and monitoring to detect opportunities for positive approaches to environmental management and to encourage methods that include affected interests in planning studies when rehabilitating or maintaining roads.

VII.2. INFLUENCE OF ENVIRONMENTAL REQUIREMENTS

Road maintenance and rehabilitation, traditionally viewed as a mundane topic for second rate engineers, are carried out today in changed circumstances and operate with a changed concept. They have a key position in preserving the value of road assets, providing improved service to road users and renewing environmental quality. The environmental requirements directly or indirectly influence all phases of maintenance and/or rehabilitation works, from planning to execution, and account for the most important component of the non-quantifiable costs and benefits.

There are two overarching aims to maintain the road network:

-- To preserve the value of investments and to provide road infrastructure and service to road users in the most economical way, and

-- To adapt the road to new circumstances responding to the requirements of the public as regards traffic flow and congestion, protection of the environment, traffic safety, and service to the community.

In line with these two orientations actions are influenced by environmental legislation and public requirements for environmental improvements, recovery and rejuvenation, i.e.:

-- In planning, environmental criteria are given more weight - even if formal multicriteria analyses are not used. In design, much emphasis is placed on achieving balanced and environmentally pleasing solutions -- using noise barriers, landscaping measures, aesthetically pleasing structures, etc. -- even if this means increased costs; this ensures the environmental values that are preferred by the public;

-- In traffic management, much consideration is given to less noisy or less polluting alternatives;

-- In periodic maintenance of road surfacings, shoulders and rest areas, the entire road space is included as part of the scope of work;

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[1] WORLD BANK (1994). *Environmental Handbook for Roads.* Technical Report for Training. The World Bank. Washington, D.C.

-- In carrying out the construction work proper, specific environmental requirements have to be followed. Construction equipment can only be operated during restricted time periods and must conform to strict noise and pollution standards; pollution due to construction materials has to be controlled and the environmental impacts of quarries, borrow pits and material treatment areas must be taken into account already when evaluating alternative road work solutions; finally, in traffic diversions attention must be paid to safety, noise and other impacts;

-- In the planning and implementation phases, the affected interests must be considered and the public at large will be consulted;

-- In traffic operation and work implementation, the impacts of roads, traffic and road works are monitored to attend to any problems that may have gone undetected.

VII.3. MODES OF IMPACTS; THEIR MEASUREMENT AND MITIGATION

One of the difficulties in measuring impact is the largely subjective nature of the environmental effects of much road work. The consequences of interactions between road work and the environment has to do with user and community 'feelings' and 'satisfaction' -- difficult variables to quantify.

Table VII.1 contains an overview of the often non-quantifiable impacts, at least in cost terms, impacts of maintenance and rehabilitation works by type of impact and by type of works. Needless to say the table is suggestive of what should be considered and some items may require an in depth study when others can be omitted. In the table the significance of the relationship is assayed, and an attempt is made to attach a positive or negative sign to the impact. It is emphasized that the impact depends on **how** the action was planned, designed and executed. In some cases if a "+" sign is possible, so is also a "-" sign; the former signifying a thoughtful, well executed action, the latter a poorly conceived and executed action. Some examples of possible mitigation measures follow to augment the table.

If one were to think of the interaction between the road system and the environment as an exchange of matter and energy, one might be able to define a rational indicator for assessing impacts. On either side of the equation, the exchange could be of natural or man made origin, its effects being permanent (eg., wastes recycled during construction or de-icing agents contaminating water sources) or temporary with the possibility of environmental recovery. Quantifying these effects and modeling in order to predict outcomes might then be possible. This could lead to accomplishing the goal of preserving the environment from the adverse effects of road work.

New approaches to analysing the environmental impacts of road works are less applicable to older roads, bridges and transport system elements. Existing infrastructure continues to be one of the causes of fragmentation of the natural environment. Since planning cannot be done to eliminate deleterious effects, they might be mitigated by measures such as constructing suitable verges, providing tunnels and bridges to enable wild animals to cross roads, and lowering speeds and noise levels. Where the effects of fragmentation cannot be mitigated it may be possible to take compensatory measures, replacing lost habitats or enhancing marginal habitats through appropriate forms of environmental improvement.

Other sources of environmental impact, and approaches to them, include the following:

Table VII.1. **Impacts of maintenance and rehabilitation works**

	Human and Social Environment					Physical and Natural Environment			
	Visual Landscape	**Noise**	**Safety**	**Land Use**	**Culture Heritage**	**Soil Erosion**	**Water**	**Air**	**Flora Fauna**
PAVED ROADS									
-- Periodic maintenance	+/-	+	+/-	+	+/-	+/0	0	+/-	0
-- Rehabilitation									
- Local	+/-	0	+	0	+/-	0	0	+/-	+/-
- Corridor	+/-	+	+	+/-	+/-	+	+/-	+/-	+/-
GRAVEL ROADS									
-- Periodic maintenance	+/-	+	+/-	+	+/-	+	0	0/-	0
-- Rehabilitation									
- Local	+/-	+	+	0	+/-	+	0	0/-	0
- Corridor	+/-	+	+	+/-	+/-	+	0	-	0
ALL ROADS									
-- Routine maintenance									
- surface related	+	+	+	0	0	+	0	0	0
- drainage	0	0	0	0	0	+	+	0	0
- road side	+/-	+	+	0	+/-	+/0	+/-	0	+/-
- signs/markings	+/-	0	+	0	+/-	0	0	0	0
- ice/snow control	0	0	+	0	0	0	-	0	-

+ : positive impact most of the time
- : negative impact most of the time
0 : no significant impact
+/- : variable impact, depending on the context, planning, design and execution

Air pollution

In planning: Minimise traffic congestion by flow management. A comprehensive evaluation of transport policies to curb auto use may be desirable in selected circumstances. Introduction of imputed prices for health effects in choosing between alternatives may also be beneficial (In Sweden the value of the health effect of air pollution for one person a year is 15,000 SEK).

In execution: Use fuel efficient construction equipment having catalytic converters; minimise traffic congestion by efficient traffic control of work zones; consider other transport policies; minimise (or restrict) the use of air polluting materials and methods, e.g. bridge paints should be water soluble.

Noise pollution

In planning: Evaluate the use of open graded asphalt and speed limits, possibly in combination; weigh the possibility of erecting noise barriers or acoustic screens during rehabilitation works; monitor noise levels in the surrounding areas. Introduce imputed prices when comparing alternatives (in Sweden the value of a person disturbed by noise during a year is 8,000 SEK. In Switzerland the budget for the rehabilitation of existing highways by installing noise screens is 70 M. Sfr).

In execution: Use noise insulated construction machines; apply speed limits and speed-bumps thoughtfully; noise emissions at night may require special steps.

Water pollution

In planning: Special care must be taken regarding (risk of) ground water pollution, erosion (rural areas) and floods; new sewage or drainage systems have to be planned, if they were not built originally. Water pollution impacts can be severe, unless protective steps are taken both in planning and execution.

In execution: Polluted waste water (for example from water jetting of old leaded paint from a steel bridge) has to be treated before disposal, because of its toxicity or because of sanitary requirements.

Soil and waste

In execution: Removed materials have to be divided into different classes for controlled deposition; some materials can be recycled and reused as construction material (e.g. asphalt concrete, concrete, fly ash).

Safety

In planning: Safety of travellers and workers on the work site has high priority. The use of traffic and works separating walls or signals is one effective way to increase safety; transition between different work phases requires good planning.

In execution: The layout of the work zone is important for access to and from the work zone, and for traffic itself and its signing and control. The workers have to be trained in measures to ensure traffic safety. The supervision of the execution of traffic safety measures at the work site is important.

Landscape and visual impacts

In planning: Landscape is a subjective "concept" that cannot be priced -- but it is highly valued. Because the road exists, planning may not be able to make a great deal of difference in upgrading the

alignment or a better fit of the road into the existing topography. However, small measures sometimes offer substantial possibilities. For example, a concrete retaining wall can be covered with rocks, plants, or designs using local materials; noise screens can be used to hide the road and to cover it from direct sight; advertising can be regulated along the road, in cities lighting can be used to produce certain effects; signs and signals can be redesigned or re-placed to improve a road's visual image; use of appropriate local vegetation can create unique views; etc.

Land use

In planning: Traditional rehabilitation works have limited or no impact on land use; their application as a positive measure to affect land use is also limited. If, however, an innovative concept of rehabilitation is adopted, it can be used to increase quality of life in neighbourhoods -- i.e. in man made environment in general -- by increasing or decreasing accessibility or road capacity as may be desired; wetlands can be recreated or rejuvenated for natural habitat of flora and fauna; etc.

Flora and fauna

In planning: Care has to be taken that the status quo does not deteriorate; natural environment can be protected in several ways: protectional vegetation, animal fences and over/under-passes, creation of natural habitat by means of wetlands and water channels, instituting traffic restrictions, etc.

In execution: The greatest positive and negative impact on flora and fauna takes place during the execution of works. Correct timing of works (e.g. avoiding nesting periods) judicious use and re-use of materials and machines, and selection of appropriate work methods, can protect significantly flora and fauna and the natural environment. Studies have shown that execution of works may have the greatest environmental impact.

VII.4. INFLUENCE OF THE COSTS

Earlier in this report, the costs were divided into two parts: quantifiable and non-quantifiable. Often costs are also divided into internal and external costs, those affecting users and the owner of the road, and those affecting the non-users, respectively. However, the division in internal and external costs is arbitrary and the major distinction is between costs that have a market value (quantifiable costs) and "costs" for which no market exists (non-quantifiable costs).

Internal costs

Most internal costs, costs to users and to the agency, can be quantified, and they are by far the most common costs involved in rehabilitation works. As implied above, the converse is also true: all costs that can be quantified can be internalised and included in benefit/cost analyses, for instance. This was the reason for dividing costs and benefits into two kinds in Chapter V: quantifiable and non-quantifiable.

External costs

These are costs which the society -- users and non-users alike -- has to pay, but which are not included in the budgets -- unless special planning efforts to mitigate or compensate environmental harm

are undertaken -- nor in user costs, and/or which cannot otherwise be quantified and internalized. Again, as discussed in Chapter V, most of the external costs are related to the environment. These external, but non-quantifiable costs have great importance and must be included in the decision-making process either as constraints -- which the plan or design transforms into a cost -- or benefit. This is a practical way of using multicriteria analysis in the framework of the engineering-economy analysis proposed in this report.

Multi-criteria analysis

The following nations use multi-criteria analysis for environmental assessment and comparison of road rehabilitation alternatives: Canada, Finland, Germany, Italy, Portugal, Spain, Sweden, Switzerland and USA. Sweden is taking an extreme position and is in the process of introducing money prices for all negative environmental impacts to be used in evaluating new investments. This is not wholly without drawbacks, because environmental costs are circumstance specific and averages will hide the issues. Even accounting for all the direct costs caused by new environmental legal obligations is very difficult. Multicriteria analysis will preserve the original dimensions of the issues and plan, design, or execute the works in a manner that either eliminates or limits negative consequences, and achieves desirable benefits.

VII.5. PRICING OF UNDESIRABLE IMPACTS: CO_2 TAXATION, AS AN EXAMPLE

Pricing of undesirable impacts is becoming increasingly popular. An effluent type of taxes have a venerable background and respond to microeconomics theory where charging is used to modify behavioural choices so as to maximise public welfare. However, the adoption of effluent taxes has been slow, because of the great complexity and political externalities of such taxes[1]. Several countries have adopted CO_2 taxes to curb increases in local (hydrocarbons and carbon monoxide) and global (greenhouse effect) pollution. Table VII.2 shows the present situation in several OECD Member countries with regard to CO_2 taxes. Given the novelty of the effluent taxes, their effectiveness should be monitored and evaluated and not taken for granted.

VII.6. DISCUSSION

Even in the context of new construction a quantitative consideration of the environment is difficult. Environmental costs of new construction is the most common theme discussed in public hearings. Take the example from Switzerland where a section of a national highway, 24km long, currently under construction, had an initial cost estimate of USD 165 million in 1967. Because the road traverses an ecologically difficult zone on a lake shore, changes in alignment and adaptations to different environmental obligations pushed the final cost estimate to USD 735 million! In this instance the external costs were internalised in the project plan, its design and construction.

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1 DORNBUSCH R. and POTERBA J. (1991). *Global Warming: Economic Policy Responses*. The MIT Press. Cambridge., for extensive discussion.

Table VII.2. **CO_2 taxation**

Nation	Taxation in use	Applied formula
Finland	no, but	unleaded - 8% of the petrol tax
Germany	no, but	unleaded - 10% of the petrol tax
Italy	no	
Japan	no	
Norway	yes	diesel appr. 6 ¢/1 fuel appr. 20 ¢/1
Portugal	no	
Spain	no	
Sweden	yes	air fuel 9.7 ¢/kg petrol 7.2 ¢/kg unleaded 3.3 ¢/kg diesel 8.9 ¢/kg
Switzerland	no, but	unleaded - 8 ¢/kg of the petrol tax
USA	no, but	in some States: - "gas guzzler tax" at initial purchase $ 400-600 - tax on the mileage to pay at the annual inspection (Cal)

For rehabilitation and maintenance the situation is much more difficult. The status quo is the road in use and the traditionally quantifiable costs of rehabilitation or maintenance works may be small and have negligible impacts. However, this conclusion can be incorrect[1]. Also, attempts to construct a scalar valued index for environmental quality -- such as a benefit/cost ratio, or a "present environmental index"[2] -- will hide the issues rather than bring them out so that they can be meaningfully addressed.

After environmental factors gained in importance and began to influence the choice and execution of maintenance and rehabilitation actions, the costs increased. The legal requirements for less polluting work methods, materials and waste treatments in all work sites, pushed in the same direction. The before-and-after difference is no longer small. However, the differences in the perceived weights of the various circumstance-specific factors make it impossible to develop average environmental

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1 Therefore, the Netherlands, for example, from 1993 onward at least 3 million guilders will be made available annually for the next 10 years to implement mitigation or compensation measures for rehabilitations of existing roads.

2 Similar to the subjective "present serviceability index" used in evaluating pavement quality.

costs -- i.e. average mitigation actions, in fact -- for maintenance and rehabilitation. Environmental impacts can, and should, be considered, and their costs calculated when possible, specific to each road section and action.

Positive environmental attitudes and proposals for mitigation or compensation actions as well as public consultation and participation throughout the project and programme planning stages help the road administration to accomplish its mission, rather than become mired in adversary proceedings where road improvements are blocked. When done this way, the external non-quantifiable "costs" are automatically internalised and quantified and brought in to have a role in the decision-making process.

Public participation is long recognised as an important element in all transport planning. It has gained new impetus for instance in the United States since the passage of the ISTEA (Intermodal Surface Transportation Efficiency Act, 1991) legislation which reinforces community based planning processes.

This changed approach for road rehabilitation and maintenance programmes will be more costly. However, by applying this approach it is possible to improve roads and the service they provide, and to integrate them better in the environment making them more acceptable in regard to community concerns. Actions and measures conceived in this way gain political and public acceptance. The public is willing to pay for the higher costs of the more extensive environmental rehabilitation, and, at the same time, the existing road itself can be maintained and rehabilitated.

Rehabilitation and maintenance must, then, be viewed as a chance to adapt the road to new conditions in a way which increases the values of both man-made neighbourhoods and natural habitat, in addition to being essential for preserving the economic value of the road asset and providing service to users. In carrying out the rehabilitation and maintenance works in an environmentally sensitive way, using recycled or non-polluting materials whenever possible, a positive service to the environment and to quality of life is done.

CHAPTER VIII

BEST PRACTICES

VIII.1. INTRODUCTION

There are three institutional components -- organisation, financing and management -- that characterise road administrations. In Chapter II Road Administration organisations in OECD countries were classified; in this Chapter they are brought into a wider context reviewing the relevant literature on road agency organisations. This is followed by a brief appraisal of financing mechanisms, especially of the designated Road Fund. After these background reviews, the managerial and technical problems of resource allocation -- the focus of the present OECD Scientific Expert Group -- are examined. Finally, this Chapter proposes guidelines for 'best practices' -- guidelines which are based on sound principles, and are flexible enough to be instituted in widely different institutional frameworks existing in OECD countries.

The answers to the survey of the Group clearly show that resource allocation and distribution is a political, economic, environmental, administrative, and technical problem. All these issues are interrelated. For example, political factors influence regional autonomy, regional balance and desirable directions of economic development; market forces affect economic growth; environmental factors and administrative boundaries and responsibilities, often of historical origin, together with the political and economic factors all motivate the functional classification of the road network. This functional classification in turn supports the technical work which underlies network development and development of priorities by road administrations for new investment, rehabilitation and maintenance.

Up-to-date functional classification becomes even more important when road administrations are faced with limited resources or when an integrated, multimodal transport system is being developed from an existing system. Proper system rationalisation can support the development of priority programmes for road and bridge improvements that maximise the effectiveness of available resources, and will help in establishing an "integrated" road system that is complementary to other modal systems.

VIII.2. ORGANISATION AND ADMINISTRATION

Structures for organisation and administration vary from country to country. They seem to be dependent on the size, population, and historical heritage of the country. Relevant from the point of

view of allocation and distribution of resources to roads is the fact that in each country it is the government -- Federal, State, or Municipal, and in some cases these together -- which has jurisdiction over the road network and also allocates resources. Intergovernmental transfers of funds, or delegation of authority to distribute road funds between different functional classes or regions of country, are normally based on required planning processes. These planning processes must take into consideration demographic, economic, environmental, and social factors and be consistent with long range financial and other plans often embodied in functional classification and expectations about land use.

Thus, in countries having a Federal organisation, planning processes are prescribed for receiving Federal road funds that are allocated by the Federal government, based either on a fixed percentage, on a formula, or the planning process itself. States that make up the federation also require planning processes as a precondition for using State or local funds; and, there are restrictions on which roads or facilities, or to what activities, the intergovernmental transfers may be made.

In countries without a Federal structure the processes are similar. The national government allocates resources on roads based on a combination of technical recommendations made by a professional staff and politics. The national road agency in turn distributes these between the regions of the country and between functional classes using planning processes and managerial techniques, *management by objectives* being the most common one, based on both politics and the use of the relevant technical information.

In areas where roads have two or more interested jurisdictions, for example main roads in cities which serve both the city and the nation, planning and political processes are prescribed for allocation of funds and selection of projects.

VIII.2.1. Road agency objectives

The effectiveness of various policies, planning requirements, funding incentives, and technical assistance to achieve these objectives has been studied (1), mostly only in the U.S.. Studies and evaluations of the effectiveness of transport agencies are almost non-existent, in spite of the chronic lack of road funds. Equally scanty has been the study of organisational structures. Most road agencies have a typical line organisation. It is not known if this is the most effective and appropriate organisation to deliver the road programme, nor is it known if the agency structure evolves depending, for example, on the size of the country, population, information technologies, road construction and maintenance technology, or other factors.

Typically a state road agency has a centralised line organisation and decision-making structure. The regional organisations, also organised along functional lines, are the executing units of the programmes, made by the central planning and programming staff. Decision-making that takes place at the regional level deals with straight forward work planning (e.g. design of rehabilitation actions, maintenance routines, snow plough routes, etc.) and less with programme planning.

A study of these issues brings with it a number of other, more technical questions which have an important bearing on the resource distribution in a road agency. Among these are the following: should decision-making be centralised or decentralised; what is the role of the regional offices in managing a road agency; how important are economies of scale and scope in managing and organising a road agency; what is the optimal number of regions into which a country or State should be divided; are there trade-offs in building a few projects fast vs. having several under construction at the same time; and, how might privatisation affect the organisation and its structure.

The survey conducted as part of the Group's work has given insights on how some of these questions are currently resolved by the road agencies.

VIII.2.2. Lessons from past studies

A review of the literature reveals that there is a shortage of research on State or country road agency organisation, its operations and performance. Larson and Rao's (2) comprehensive study of the U.S. State Highway Agencies' capital programme management practices illustrates the complexity of these practices and the variance that exists between the States. Talvitie and Sikow (3) studied productivity growth in a country's road agency and Hartgen (4) compares the productivity and effectiveness of state highway agencies over time in the U.S.

Larson and Rao cite a 1984 survey of the U.S. state highway professionals (5) whose responses led to the conclusion that transport is perceived and used by state policy makers as means to ends other than those directly impacting transport, "sometimes to the discomfort of transportation professionals." Larson and Rao venture to guess that "in a more competitive environment for resources, highway capital programmes will likely require a new focus and broader ranging goals", but they maintain that there is no "right way" to manage the highway capital programme and argue for "directed autonomy" to allow creative approaches to be developed by individual States.

Hartgen develops "State profiles" to gauge a State's performance. His findings suggest that explanations based on traffic, weather, climate, taxation, etc. are not sufficient and not even relevant to describe agency performance. Finding a widening gap between States between 1984 to 1989, Hartgen proposes that road agency performance is more related to "political environment, managerial climate, and capitalization philosophy" than the above variables. More recently Humphrey, Meyer, and Walton (6) reviewed methods -- and implicitly also challenge Hartgen's methodology -- used for comparing State highway performance.

Talvitie and Sikow's studies yielded information about management and organisational structure. Their finding that road capital programme is subject to substantial economies of scale in certain ranges implies that there is an optimal number of highway regions (in Finland four or five, not the actual 13). The number of highway regions, or a reduction in them, certainly depends on "political environment, managerial climate, and capitalisation philosophy" as advised by Hartgen.

An interesting finding was the strong effect on the costs of management variables describing resource distribution. (Slow) speed of construction, (large) number of projects, (large) size of own (fixed) labour force had significant negative effect on cost efficiency and productivity. This, supports the Larson and Rao and the AASHTO finding that "project selection is influenced most heavily by legislators and boards or commissions". If, however, performance is measured exclusively in terms of getting more roads or better quality product for dollar spent, this would conflict with the interests in management accountability and improved agency performance.

The fact that resource distribution significantly affects costs and performance can be especially challenging to management. Substantial changes in the labour force, resource distribution and rehabilitation programming practices, organisation and technology are difficult to make, because of the "political environment, managerial climate and capitalisation philosophy", or because of the leverage of "legislators and boards or commissions", as carefully worded by Hartgen, and Larson and Rao. To this list should be added the profession's neglect of highway construction and information technologies' effect on organisational structure.

This short review of past studies indicates that resource allocation and distribution is important not only to road condition, as the graphs in Chapter IV show, but also to agency performance. Planning processes employed -- and, indeed, required -- for allocating and distributing resources are, therefore, as important for a well managed road system as ensuring that free competition exists in the market and that organisational reforms keep pace with technological development.

VIII.2.3. Directed autonomy

The discussion above presented key ingredients for improved management of roads referring to "political environment, managerial climate, and capitalization philosophy", "directed autonomy .. allowing creativity", and "balance between the need for direction and control on the one hand and freedom and flexibility on the other depending on the political, cultural, and demographic circumstances" (of each country).

There are several approaches to resolving the conflicts within public organisations, when trying to achieve the objectives of accountability, direction, control, flexibility, freedom and creativity. One of these is organisational reform that will enable management to manage efficiently.

As mentioned, the typical road agency organisation structure is a line organisation. This organisational structure is based on the technocratic idea that each line has its own stand-alone product output, and that within the line output (e.g. rehabilitated road), inputs (e.g. factor prices), and management (e.g. the number of projects) are not separable from each other. This is the centralised line organisation. However, this may not be the most efficient organisation structure.

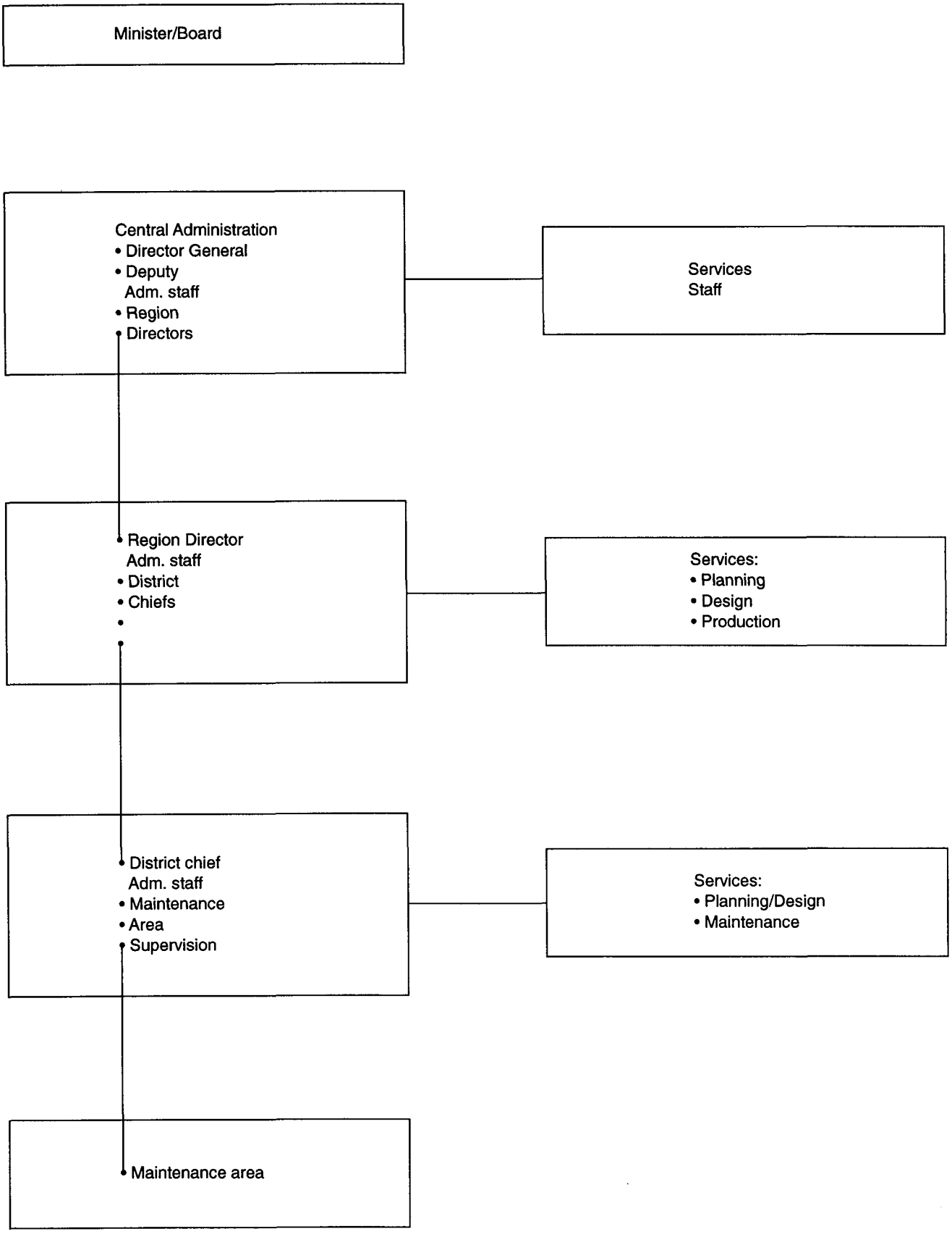
On the basis of the studies, cited above, it can be inferred that maintenance, rehabilitation and new construction are not separable either from each other or from management, but that factor inputs are. Translated into practical terms this means that the Central Administration must have a *comprehensive responsibility* regarding the distribution of monies within the country (or for recommending to the Board or the Ministry) and between the main activities of new investment, rehabilitation and maintenance. It further suggests that the Directorate of the Agency should be composed of the Chief Executive/Director General and the Region Directors and form a *general purpose management team.*

This management team will have support staff, presumably at the headquarters which, at the request of the Directorate, undertakes studies regarding resource allocation and distribution, develops policy proposals, and provides other services of national significance.

Following the results and reasoning above, the regional agency, which is responsible for executing the national programmes, must also have a *comprehensive responsibility* to manage all its outputs, given a broad distribution of monies and a statement of common policies. The region director should be accountable (to the Director General) for design, construction, rehabilitation and maintenance once the policy has been established. The region director will "own" the policy because he was a member of the team that formulated and recommended it.

The organisational structure (ref. Figure VIII.1) can be called a *fractal organisation*, because each lower level is a replica of the higher level. This organisational structure does not mean that everything is delegated. The words *general purpose* and *comprehensive responsibility* apply to management of activities which are performed at a given level; e.g. programming and executing road condition surveys, rehabilitation or maintenance of roads at the regional level, etc. Centralisation, decentralisation and

Figure VIII.1. **"Fractal" organisation for a highway agency**



delegation depend to a large extent on technology, especially information technology. Organisational structure should not stay in the way of efficiently employing information technology.

If the country is divided into numerous regions the size of the Directorate can become too big and make it unmanageable. It, therefore, is important that the number of regions is optimally small. Presumably this depends on the level of technology and information systems utilised in the country. Studies are, therefore, in order to determine how many regions and how many fractals a country should have[1].

Needless to say, the issue of organisational structure and decentralisation of authority and decision-making has political importance. An organisational reform is always a process. The conclusion reached in the productivity studies applies also to organisation: the study of the organisation to fulfil its mission is important. For resource allocation and distribution to serve the needs of the public effectively, it is important that organisational structures keep pace with changes in society and developments in technology.

VIII.2.4. Changing context of rehabilitation and maintenance

It was noted in Chapter VII that "During the life cycle of a road or a network the responsibilities and life styles of people, their travel demands, and communities as a whole will change. The road network has to be adapted to these new circumstances". The changing context of road rehabilitation and maintenance is important and profoundly affects them both. It has been noted in several places in this report that today road rehabilitation and maintenance -- and road construction as well -- operate in a new environment and with a new concept. The objective of maintenance and rehabilitation is no longer to simply keep the road in appropriate condition as a structure, the road also must change in response to other external changes in its environment.

It was proposed for this reason, that road administration organisation and managerial and analytical procedures accommodate training needs of personnel in environmental and aesthetic assessment for recognising opportunities for positive approaches to environmental improvement and to consider affected interests early in the studies that are undertaken. Rehabilitation and maintenance have experienced a change in concept and content: they are meant to preserve the value of the investment **and** to improve the environment.

VIII.3. FUNDING AND TAXATION OF ROAD USE

VIII.3.1. Introduction

The question of funding and levying taxes on road use was considered to be outside the scope of the Expert Group's activities. Nevertheless, that question is so important that it cannot be left without a short commentary.

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[1] A hypothesis can also be made that a line organisation could be more efficient with low level technology and insufficient information systems, and a fractal organisation only becomes possible with the employment of more advanced technologies and information systems. More research and experimentation is needed on this matter. For example, the organisational structure existing in federally organised countries has not been investigated from the economic point of view.

In most participating countries allocation of the road funds is done from the country's general budget. Earmarking is done only in Switzerland and in (some States of) the U.S. Of course, all or a part of toll revenues are earmarked to the toll roads in Austria, France, Italy, Norway, Spain, the U.S., and elsewhere where toll roads exist. In these cases the level of toll charges is regulated. A part of the toll revenue may be dedicated to other purposes -- public transit or amelioration of automotive air pollution -- to make the tolls more acceptable to the public.

The survey of Member countries showed a strong interest in "earmarked" funding sources. These earmarked funds could come from existing gasoline and other user taxes, and tolls. This is not surprising because the level of total funding per kilometre of road length showed considerable variance among the Member countries, from USD 7 000 to 125 000 per km per year! Most countries spend between USD 15 000 and 45 000 per km annually, including investment, rehabilitation, maintenance, operations and administrative expenses.

The division of funds between different activities showed similar variance. The maximum spent for new construction was 80 per cent of the total expenditures, and the minimum was 20 per cent. Generally, the percentage devoted to new construction was 25 - 50 per cent.

The wide variance in these figures undoubtedly represents the widely different environmental conditions, past expenditure for the road network, and growth in travel demand in the country. Similarly, it reflects the sore need for improved analytical procedures to allocate monies to roads and to distribute them between functional classes and remedial activities.

VIII.3.2. Basis for road user contributions

In Chapter IV a comprehensive framework was proposed for allocation and distribution of road funds. In that framework, minimisation of total transport costs -- the agency and the user costs -- determined both the allocation and distribution of funds and the condition standard of roads. According to the survey, few, if any, of the countries used user costs to help determine the road condition standard. Instead, the road condition standards were determined by engineering and other considerations.

Figure I.2 showed that the user costs were three fourths of total transport costs when the daily demand flow is as low as 300 vehicles/day **if** an "optimal" road rehabilitation and maintenance policy is observed. The big **IF** is the "optimal" rehabilitation/maintenance policy and the agency costs it entails.

It is not known how much the present budgets are below the "optimal". The feeling is, however, that in most countries the present road allocations are well below the "optimal", but if increased road allocation is desired, it must come from the road users themselves.

The issue is not, as road users maintain, that they already bestow more to government revenues than is spent on roads. The issue is that governments do not have surpluses, but instead experience shortages of tax revenues in most countries. It also is debatable whether the road users pay too much; road transport causes external costs on environment, noise, and congestion for which there is no market at present. There also is considerable evidence of cross-subsidisation from cars to trucks, especially to the heavier trucks.

There is a need for the governments to demonstrate to road users that they would be better off, in terms of reduced user costs, if they paid more to allow road improvement programmes to be carried out (in "optimal" fashion, of course). The converse is also true; the road user groups -- the trade

associations, shippers, carriers, economic development and public interest groups -- need to take their case to the government and show what the consequences of *status quo* road budget would be, and what would be gained by incremental increases in road allocations in terms of industrial development, job creation, mobility, and sustained economic performance.

These facts, the road users claiming to pay too much and the government allocating too little monies to roads, point again to the need for having better information and better analytical procedures for determining road budgets and standards. The analytical framework elaborated in Chapter IV of this report, and the Road and Bridge Management System on which it is based, can provide such information to help resolve the conflict between feelings and values.

VIII.3.3. Types of road user charges

The customary public finance principles of economic efficiency, administrative cost, and equity, in addition to cost recovery, apply in developing the road user charges. In order to satisfy these criteria several kinds of user charges are required and even then compromises are required:

i. Variable charges -- fuel charges -- are good because they are related to usage and very inexpensive to collect; the fuel charges relate both to road wear and to externalities, many of which correlate closely with fuel consumed.

ii. Fixed annual charges -- vehicle charges -- are appropriate to influence the composition of vehicle fleet to become less polluting.

iii. Tolls; while tolls are relatively expensive to collect, their collection technology is improving with great strides. Tolls are equitable; they have the advantage of enabling pricing of the externalities and localising the pricing[1]; that is, users of better facilities can be made to pay more. Tolls may also receive user acceptance because users perceive a link between toll and facility condition. Tolls are suitable for collecting revenues from foreign vehicles[2].

iv. Heavy vehicle charges, based on the axle loads and distance driven. As for tolls, efficient collection mechanisms have been developed. New Zealand, for example, collects axle load-distance charge using a hubodometer -- odometer attached to the hubcap -- quite inexpensively, 2-3 per cent of revenues. It has been suggested that a hubodometer is less expensive than most existing systems, weight-distance or simply gross weight charges which do not induce truckers to choose axle systems which would minimise road damage.

VIII.3.4. Road fund

A Road Fund is a holding of dedicated revenues collected as road user charges. Earmarking revenues in the form of a Road Fund has several advantages and disadvantages. The most apparent advantages are:

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[1] The newest toll charging mechanisms can also be used to localise fuel charges and earmarking them not only to roads in general but roads in that jurisdiction and geographical area.

[2] This is a very important feature in the European context, especially for the former Comecon countries where foreign traffic can be substantial and governmental funds to build roads are unduly limited. Tolls are, of course, a prominent feature of the so called BOT concession facilities.

i. A Road Fund makes for a stable road budget and avoids "political" diversion of road user charges.

ii. Stable road budget promotes efficient programming and may contribute toward lower contracting costs.

iii. A Road Fund makes increasing user charges more acceptable because their usage can be identified and monitored.

iv. A Road Fund facilitates cost recovery and equity; beneficiaries and those who pay can be matched.

v. A link between payments and benefits may promote more efficient management of funds and increase sense of accountability because the programmes can be easily monitored.

The most common disadvantages are:

i. A Road Fund entails a cost in terms of loss of budgetary freedom, especially in unforeseen fiscal difficulties.

ii. A Road Fund cannot be supported theoretically; it could lead to distortions between different sectors of the economy; in particular, it could lead to overspending in the road sector.

iii. Road Funds have not been successful in ensuring adequate monies for maintenance; there has been a tendency to use road fund monies for new construction.

iv. Other disappointing experiences with some earmarking experiments.

Lessons from earmarked road fund experiments, and the identified "cons", propose that the following factors are important if a dedicated road fund is contemplated:

i. The planning process and the types of expenditures and functional classes for which road fund can be used must be clearly specified.

ii. The yearly level of expenditure, the road sector allocation and its distribution between the major activities -- new construction, rehabilitation, and maintenance, should be determined by reliable, periodically updated data and appropriate analytical procedures -- the Road and Bridge Management System and the Analytical Procedure described in Chapter I -- not by the availability of monies.

iii. Proper political control of road management, in addition to auditing and accounting safeguards, which covers both the money usage and the performance of the road administration, should be exercised.

iv. The Road Fund authorisation should be periodic, e.g. four years at a time to maintain "checks and balances".

Funding and road user charges are important issues. Road user costs dominate the transport costs, already at demand levels of 5000 veh/day, the agency costs are only 10 per cent of the total costs, **if** the "optimal" maintenance policy is followed.

Consequently economic returns of maintenance and rehabilitation are high, often 30-60 per cent. At demand levels of 2500 veh/day, annual road user costs on a road in poor condition are USD 25 000/km higher than on a good road. This is 2-3 times higher than the costs of maintaining the road in good condition.

These descriptive facts are significant and point toward the critical importance of road user charges in planning and determining multi-year road programmes. Equally important is the inclusion of user groups to participate in possible raising and earmarking of the user fees.

VIII.4. MODELS FOR BEST PRACTICES

VIII.4.1. Three kinds of models

The above brief survey of current governmental practices, administrative arrangements, relevant literature, and comments on funding practices, demonstrates that, regardless of organisation structure, resource allocation and distribution decisions of road funds are done at three levels -- network, programme, and project -- and that this is important for good and accepted practices. The problem lies however in how to provide and process the information to best support this practice; that is, using the analytical framework proposed in Chapter I. At present the allocation/distribution decisions may be more based on intuition than facts in many, and perhaps most, countries.

Before describing the desired -- and necessary -- information and analytical needs and outputs at each level, the basic structure of the road resource allocation/distribution problem is once again reviewed. In Chapter II it was found that regardless of a country's governmental or administrative organisation there always exists a hierarchical decision-making situation: at the highest level the decision-maker is confronted with the need to allocate resources at the network level between programmes and subnetworks[1]. After the network-programme level allocation a project level multi-year plan is formulated and, finally, each individual project designed for implementation. These three levels are a way to simplify the complex decision-making problem and permit development of models which serve the decision-makers and support the kinds of decisions to be taken at each level.

VIII.4.2. The network level

The focus of the network level model is on policy and intelligence: the long run road condition to be provided, total (desired and actual) spending by region of the country, trade-offs between new investment and routine maintenance, scrutiny that the policy followed is consistent with other transport policies, etc. Operationally, the model stresses broad categories of actions and spending, distribution of monies between functional classes of roads, and relation of spending to "optimal" road condition sought and preservation of the road asset. The network model can also show the present level of road user charges and their relation to the budget. The network level intelligence also serves the Ministry's

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[1] In some countries the resources are allocated first between programmes -- development, rehabilitation, routine maintenance -- and then between subnetworks -- defined either functionally or administratively; in other countries the allocation of resources is done in the reverse order, first between functional or administrative classes and then between programmes. The order in which the allocation is done is related both to the evolution of governmental structures and to the sources of funds available for different programmes or subnetworks.

and the Road Administration's needs to inform the public about their policies, and provides an informed basis for public debate about these policies.

Figure VIII.2 once again portrays this optimisation problem in resource allocation and distribution[1]. The objective is to minimise the total of agency and user costs. This optimisation determines both the optimal road condition -- expressed in several dimensions (evenness, distress, bearing capacity, rut depth) -- and the optimal budget. It is shown in the figure that both a budget constraint and standard constraint(s) are possible, but that both constraints will cost money in the long run -- and often also in the short run. As is seen from the figure, the consequences of non-optimal budgets and standards to users can be quantified. The method then allows examination of policies in which road users are given an opportunity to pay more to improve the road condition. (See also the earlier discussion on some implications of the Road Fund set up for this purpose).

In summary, at network level the long term goal, the optimal road condition distribution and associated budget, is sought; at this level budgets for various subnetworks -- by functional or administrative class, by region, by traffic volume -- are determined and a distribution for remedial actions is suggested. This is done by the Ministry and the Road Administration managers, and their model -- 'the network level model' -- is tailored to meet their demands and omit unnecessary technical details.

VIII.4.3. The programme level

Figure VIII.3 (and Figure I.3) illustrate schematically the function of the programme level between the network and project levels. The programme level focuses on locally and regionally important information: what projects will be implemented, when, what action will be undertaken, how long is the project anticipated to last, what is the approximate budget, what other ameliorative works are contemplated? The programme level output, a multi-year schedule of projects, consistent with the network level prescriptions is, thus, important both to the agency and to the immediately affected interest groups and serves as a major information tool. It provides quantitative information about how the programme makes a contribution toward implementing the road policy.

The multi-year programme is done in interaction with project-specific decisions, but is separate from them. It conforms to the budget and action distribution, "optimised" at the network level in the central administration, and seeks to achieve the goal in a most economical manner subject to technical and local constraints. These local constraints include interdependencies between links, environmental constraints (e.g. utilise existing asphalt plants or provide rationale for their location, because these plants and quarries normally require an environmental permit), local needs -- economic and social -- with respect to road conditions, local pinpoint knowledge about factor prices, etc.

The programme procedures are different from the network and project level models, but compatible and are designed to meet the needs of the technical and policy staff and also serve local information needs. Because the future cannot be predicted accurately -- owing to technology development, changes in peoples values, and changes in economic "climate" -- the *planning process* implied by Figure VIII.3 is repeated periodically, say every 3-5 years, to check that the long term optimum and the multi-year programme stay contemporary.

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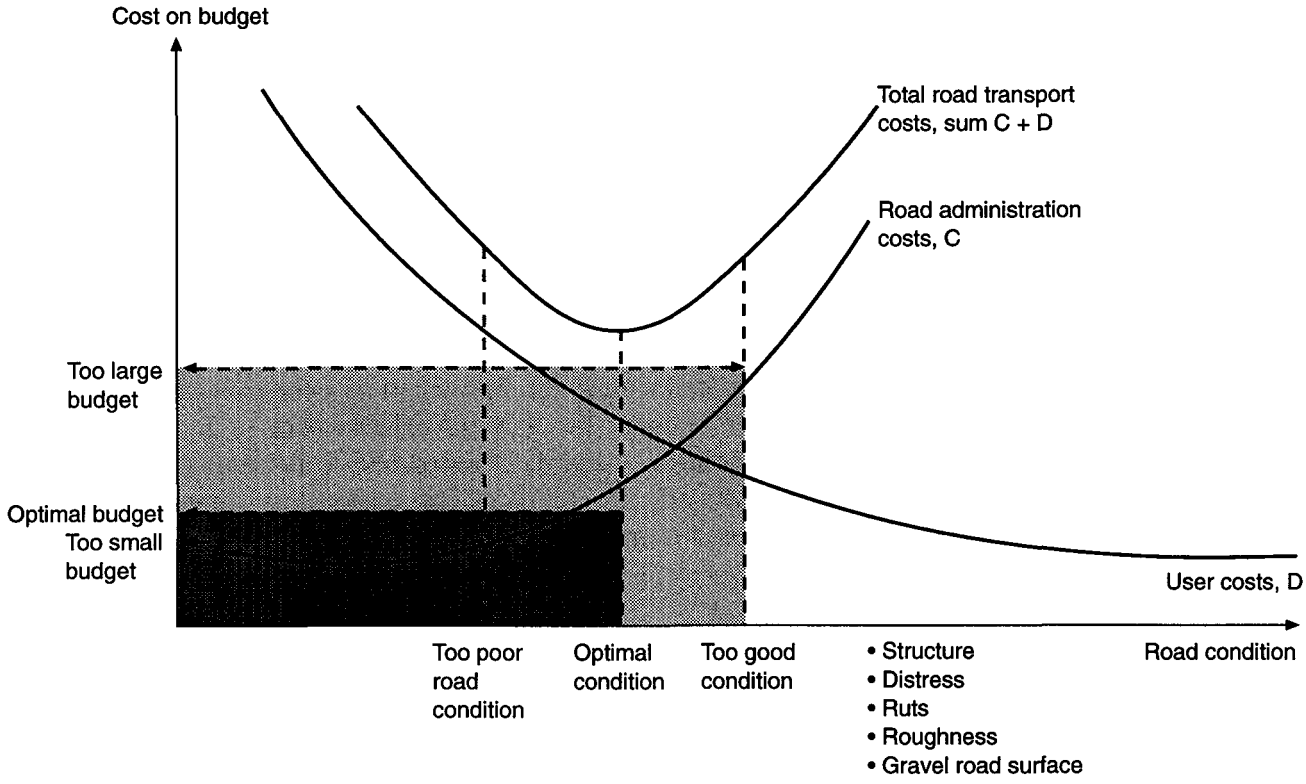
[1] This figure applies both to network and project levels; in the former case it represents a group of links, e.g. Main Roads, and in the latter case the specific road being rehabilitated.

Figure VIII.2. **Optimisation of road condition and road budget**



VIII.4.4. The project level

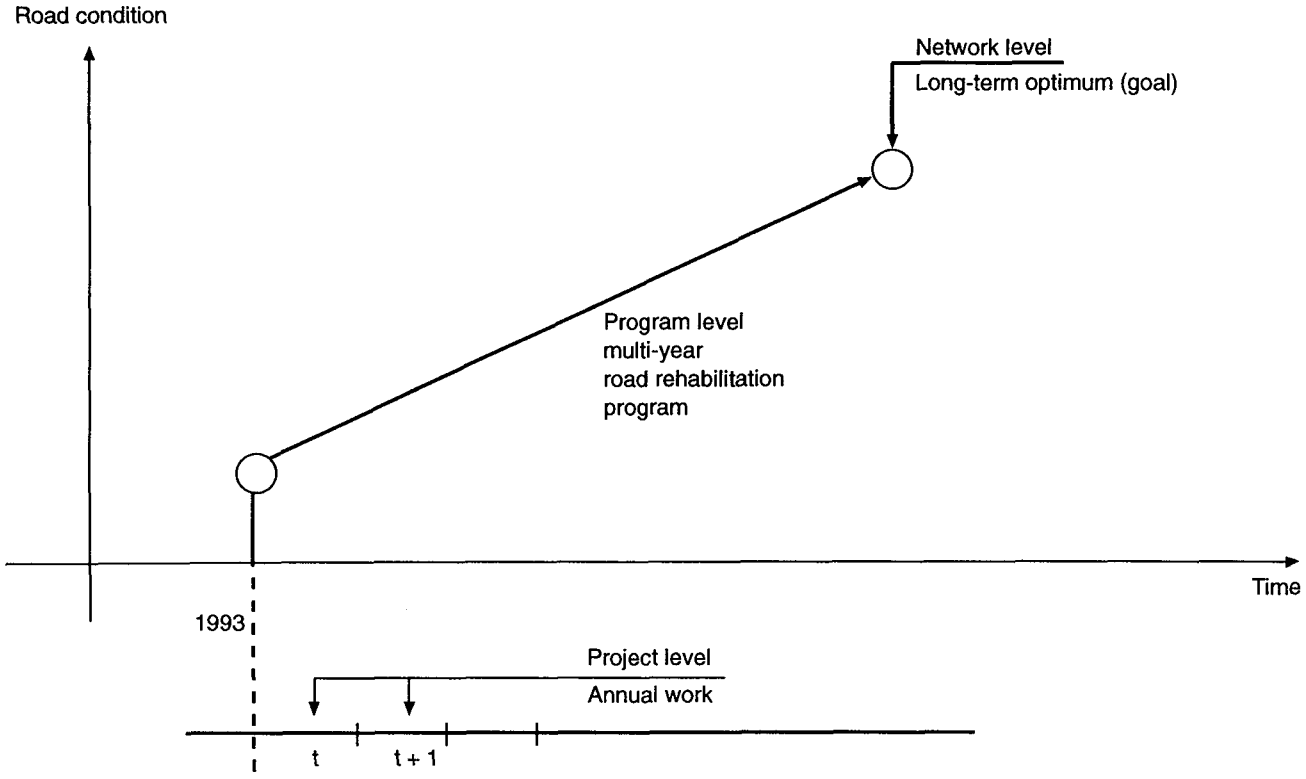
The project level is the annual work programme, derived from the multi-year plan. It is basically an engineering document. The project level adds intensive local knowledge about the "engineering history" of the road links to road management decisions. It is concerned with how exactly the project will be executed, e.g. the design, timing, and contracting. It may contain modules or expert systems on pavement mix design, use of levelling courses, optimisation of engineering works, etc.

The project level also deals with all associated details of the action; designs to ameliorate environmental impacts, traffic management questions, nuisances during construction, etc.

VIII.5. INFORMATION NEEDS FOR BEST PRACTICES

Best practices in road resource allocation and distribution, and in road user charges which are tied to them -- even if in no other way than travel demand -- can only be based on good data and good analytical procedures. All levels of governments -- federal, state, and local -- involved in road keeping share common needs in developing road improvement programmes and evaluating their impacts. The

Figure VIII.3. **Multi-year planning process in rehabilitation and maintenance**



major difference is in the level of detail and breadth. Project specific analyses require intensive data support and national studies require extensive data support.

Typically a Road Agency requires the following information[1] in order to develop the analytical procedures and parameters required in resource allocation.

Physical information

i. Road link inventory (location, geometry, furniture, land use; etc.)
ii. Pavement structure (type, strength, depth, drainage, sub soil, surface; possibly other info)
iii. Pavement condition (roughness, distress, rutting, texture, deflection; etc.)
iv. Structures (foundation, superstructure, material, restrictions; etc.)
v. Structures condition (inspection system)

Operating information

vi. Traffic volume (AADT and seasonal traffic variations, vehicle composition, axle loadings, truck size and weight; etc.)
vii. Operating characteristics (road geometry, traffic control, adjacent development; etc.)

[1] The items in parentheses are for example, only. A more complete list for road data can be found in Paterson and Scullion, 1990; see also HPMS).

viii. System operation (speed, degree of congestion and duration, daily variations in operating characteristics)
ix. Safety (fatalities, injuries, property damage, other accident details)

Implementation

x. Implementation information (programmed action, action taken, total cost, unit cost, time, quality assurance)
xi. Other implementation information (info on routine maintenance, unusual events, contract type; etc.)

System usage

xii. Passenger travel surveys (origin-destination studies, other travel demand and system usage studies, user cost components)
xiii. Truck and goods movement surveys (origin-destination, type of commodity, route, type of load -FTL,LTL, etc., operating costs)
xiv. Vehicle statistics (vehicle characteristics for fuel, emissions, age distribution, vehicle capital and operating costs, emission factors; etc.)

Socioeconomic information

xv. Socioeconomic and land use information needed in travel demand, economic impact studies

Environmental information

xvi. Pollutant concentrations and pollutant sources, environmentally sensitive areas, other environmental information on which the road or traffic have influence

This incomplete list gives an idea of the overwhelming complexity of the information systems needed in road management. While this complexity may seem daunting, it is nonetheless imperative that reliable data collection systems be in place to address the areas above and support the overall informal system.

It is appropriate to conclude this section by reiterating guidelines for developing data systems.

-- integrate data, eliminate duplication, and minimise the burden placed on all participants (of users and suppliers)
  - ♦ determine exactly what is needed beforehand
  - ♦ tailor the data system for its intended use
  - ♦ use sampling whenever possible

-- meet the data needs of data suppliers as well as end users
  - ♦ make success important to both parties

-- eliminate the need for special data collection efforts
  - ♦ modify existing data systems rather than conducting special studies or developing new systems

-- ensure data consistency and accuracy
  - ♦ check data accuracy continuously
  - ♦ provide feedback to data suppliers
  - ♦ audit data quality randomly
  - ♦ publish data compilations and results of audits

Relation of general information needs to the specific data needs of the RBMS

This section shows that the general information needs of a Road administration sketched above also serve well the Road and Bridge Management System and would require no large changes in the current best practices in data collection.

The network level: On the national (Federal/State) level, funds are allocated to roads, and often jointly to all transport facilities, by the responsible (general purpose) governments. Once allocated, road agencies at these levels distribute the funds between regions, functional classes of road networks, and activities -- new investment, rehabilitation, maintenance -- based on elaborate planning processes and analytical procedures which encompass political, economic, social, environmental, and technical factors. The network level model focuses on those considerations which the political and managerial decision-makers consider important.

The aggregate distribution of road funds at the network level is done without a specific object, road, bridge or action in mind. The distribution concerns regions (states, provinces, municipalities), functional road class, and activity - normally new investment, rehabilitation, maintenance[1]; in some cases only investment and maintenance. This distribution may entail restrictions on uses of money; for example Federal monies may only be used on Federal roads.

In order to distribute monies between regions, functional classes, and activities, a road agency should have expertise, data, software and hardware, and analytical procedures to:

i. Estimate aggregate travel demands and loadings by heavy vehicles on the road network,
ii. Establish the physical condition of the road network with a degree of precision and detail appropriate at this level,
iii. Suggest a distribution of remedial actions and associated budgets to achieve a specified objective or objectives (e.g. minimisation of total (weighted) transport costs),
iv. Evaluate consequences of implementation delays due to budget constraints on road condition and future budgets,
v. Calculate the costs and benefits of the remedial actions in sufficient detail,
vi. Relate the distribution of monies to other factors (environment, economy, taxation, social concerns and equity, etc.) seen relevant to the road programme,

The programme level: The second level prioritises improvements and determines the remedial actions and priorities in an overall road improvement programme. The road improvement programme is usually proposed by the regional (district, local) agency and approved by the national (Federal, State) administration. In some cases the approval simply means observation of stipulated guidelines which

[1] These activities are further divided into specific actions: adding lanes, building a road segment, bridge deck improvement, type of rehabilitation action, and type of routine maintenance actions. What is important to note here that no specific link or object is identified.

may specify factors, objectives, co-operation of affected local officials, public participation, environmental criteria, and consistency with other modes of transport.

In order to formulate a strategic road improvement programme the regional road agency should have expertise, data, software and hardware, and analytical procedures to:

i. Assign estimated travel demands and loadings by heavy vehicles on the road links,
ii. Establish physical condition of the road links in necessary detail,
iii. Choose the road links and propose the remedial actions to be undertaken on these links consistent with the budget,
iv. Prioritise suggested improvements consistent with the programme objectives and budgets established at the network level,
v. Incorporate the remedial actions and priorities into an overall road multi year improvement programme,

The project level: At this level the project is designed by the regional (local) road agency or by a consultant, and in some cases by a contractor, suitable in detail for execution by the contractor or the road agency's own work force. The project level model is a pure engineering tool but which accepts information from the network level.

In order to choose the performance specifications and other details of particular remedial action -- widening the road link, building shoulders, reconstructing the structural pavement courses, layer thickness, particulars of the asphalt mix, etc. -- consistent with the road improvement programme the regional road agency should have expertise, data, software and hardware, and analytical procedures to:

i. Know the travel demands and loadings by heavy vehicles on the road link to design the remedial action,
ii. Know the original design and present physical condition of the road link, and the history of prior remedial actions,
iii. Know the environmental factors pertaining to the road link which influence the design of the remedial action,
iv. Calculate the costs of the chosen design,
v. Know the procedures for executing the design to confirm with warranted quality,

It is recommended that the OECD RTR Programme launch a comprehensive study to agree on common definitions of desired data and describe procedures for collecting and maintaining that data in a GIS (Geographic Information System) environment. Technologies offer inviting opportunities, not imaginable before.

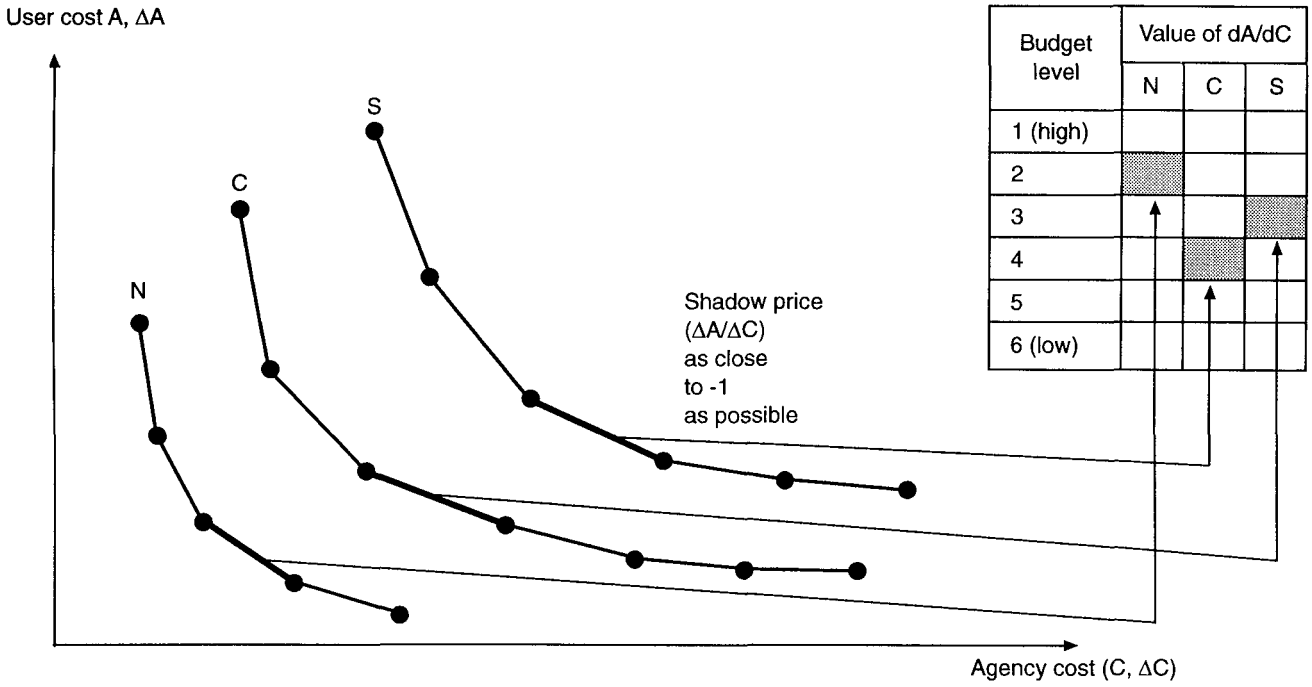
VIII.6. TRADE-OFFS WITH OTHER PROGRAMMES, DISTRIBUTION OF MONIES BETWEEN PROGRAMMES, THE BUDGET CONSTRAINT

As mentioned earlier, the principles of determining optimal budgets and standards should also be followed in allocating monies to investment, rehabilitation and routine maintenance, and in dividing the monies between functional classes of roads, and between regions of the country. The simple reason is that all these issues are interrelated and should be recognised as such. This requires a comprehensive

Road and Bridge Management System and associated analytical procedures imbedded in Figures VIII.2 and VIII.3.

In this section of the Chapter a practical method for distributing scarce resources between competing interests is proposed. The principle for doing this is the one explained in Chapter IV, and again shown in Figure VIII.4, and it must take place at the network, that is, Central Administration level. Here it is assumed that the allocation question concerns the apportionment of monies between regions -- North, Central, South -- and traffic volume classes. An analogous procedure can be applied for other distribution questions.

Figure VIII.4. **Budget distribution between regions - an illustration**



Optimal total budget = constrained regional budget levels (shadow price closest to -1).

In the most optimistic and in reality idealistic case, when no budget constraint exists, it suffices to determine the minimum total cost point for each programme separately and record the associated budget. When there is a budget constraint or standards to be achieved, as is normally the case, the procedure is more difficult but systematic. The proposed allocation criterion, equalisation of the shadow price, is illustrated in the upper left hand corner figure. Again, the principles of Section IV.6 are applied. The change in user costs (dA) is plotted against the change in agency costs (dC); the slope of the quotient dA/dC is called the shadow price as it tells how much additional benefit can be obtained for an extra ECU spent. When the shadow prices for different programmes are equalised it is not economically efficient to transfer monies from a programme to another.

This is accomplished by varying the **k-factor** (same value being used for each Region) until a solution is found whose agency cost equals the budget constraint. In practice it is often more

illustrative to proceed in the manner shown in Figure VIII.4. Starting from an unconstrained budget allocation, budgets are reduced stepwise for each Region's sub-network (in this example, 3 regions). Using an algorithm, changes in user and agency costs are calculated and sub-network budgets having the shadow price values closest to -1 are chosen as the constrained optima.

Again, it is emphasised that the solution obtained is a engineering-economic solution. It is subject to many uncertainties involved in calculating user costs[1] and assumes equal (marginal) utility of money among all user groups. Therefore, there may be strong social and political reasons why the engineering-economic solution will not be observed. These reasons range from the desire to have uniform standard on a route, in itself an engineering consideration, to issues of regional policy, to equity between different user groups. These matters must be decided through a democratic process which each country has implemented in its own fashion, but what can be provided is the approximate economic costs of following a given policy.

Often this deviation from optimal policy manifests itself in a tendency to give greater apportionment to low volume roads than would be optimal in engineering sense, or to pursue road investments in a region where there is but little economic activity. However, there can be strong social reasons why low volume roads need be kept in better form than would be economically efficient.

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[1] For example, graph VIII.4 implies that all users have a user cost curve as shown. That of course is not true, there is a wide variance in costs between users. The hypothetical model is a statistical model which hides variances. However, the model is a useful construct and true in average.

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